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Three Dimensional PIC Simulations of the Transparent and Eggbeater Cathodes in the Michigan Relativistic Magnetron

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A novel relativistic magnetron priming technique consisting of either a main center cathode and several satellite cathodes (eggbeater design) or just the satellite cathodes (transparent cathode design [Fuks and Schamiloglu, 2005]) is investigated using the three-dimensional electromagnetic, particle in cell code ICEPIC. Both these cathode designs rely on RF field penetration into the cathode region to enhance performance. This priming technique is thought to allow for larger amplitudes of the synchronous E_θ field in the electron hub region which in turn hastens the capture of electrons into spokes. This technique effectively eliminates mode competition with the Pi mode amplitude dominating the other modes by at least a factor of 25. The A6-3 Michigan magnetron was used for all simulations [Lopez 2002]. For both cathode designs the number, radial placement and orientation of the satellite strips were allowed to vary over several axial magnetic field values so that an optimization with respect to output power and efficiency could be determined at a given magnetic field. Performance optimization was achieved for both cathode configurations at B=3.2 kG with nine satellite cathodes at a radial placement of 1.75 times the main cathode radius (Figure 2). A power output efficiency of 35% and an output power exceeding 550 MW was measured for both designs at optimum parameters. Efficiency and output power decreased as satellite radial placement was increased from optimum (Figure 3). The range of satellite cathode placement extended from greater than 35% output power efficiency at a satellite radial position of 1.75 times the cathode radius to 22% efficiency at a radial position of 2.93 times the cathode radius. Moreover, it was observed in some cases that satellite cathode orientation (with respect to the slow wave structure) provided an additional ~50 MW of output power.

Transparent and eggbeater cathode designs were simulated with 3, 6 and 9 satellite cathodes. It was found that the number of satellite cathodes did affect the magnetron output performance characteristics. For example, unlike the 6 and 9 satellite cathode simulations, the 3 cathode transparent design was robust with respect to cathode placement. Power efficiencies for satellite cathode radial placements at 1.75, 2.0 and 2.3 times the cathode radius all yielded efficiencies in the 30% range and output powers ~ 500 MW. Only after satellite cathode radius exceeded 2.3 times the main cathode radius did efficiencies start to drop off significantly for the transparent 3 cathode design.

1. Mikhail Fuks and Edl Schamiloglu "Rapid Start of Oscillations in a magnetron with a Transparent Cathode", PRL **95**, 11 November 2005
2. Lopez et al, "Cathode Effects on a Relativistic Magnetron Driven by a Microsecond E-beam Accelerator," IEEE Trans. Plasma Sci., 2002.

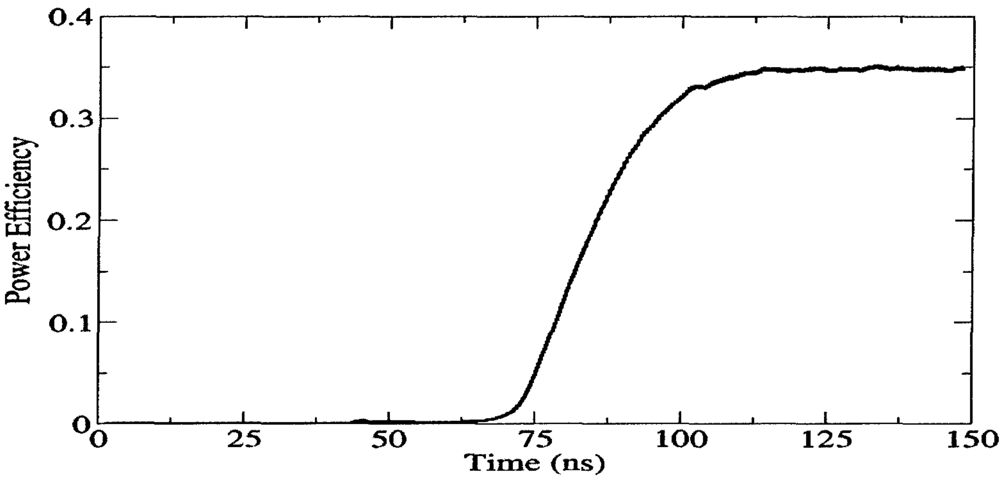

Figure 1. Efficiency for the University of Michigan A6-3 with "Eggbeater" cathode B=3.2 kG.

Figure 2. Power, A K Voltage, and current of the University of Michigan A6-3 with "eggbeater" cathode at B =3.2 kG. The output power exceeds the conventional design by a factor of two [Lopez, 2002].

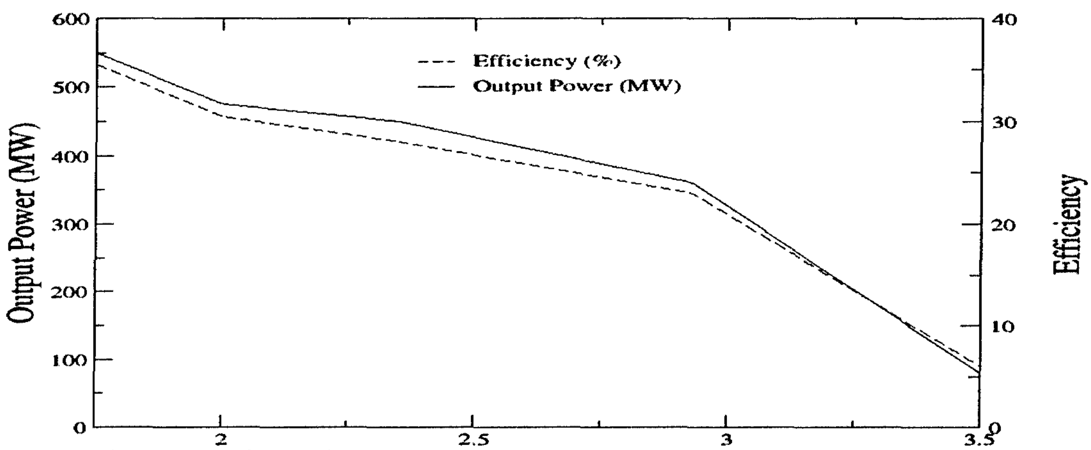

Figure 3. Satellite Radial Placement (Main Cathode Radius)